

[0080] In Step 545 the graphic scene is drawn on the display or other video hardware based on updated state data. In an actual prototype device this is accomplished by calling routines from the OpenGL application programming interface. However, other graphics libraries such as Direct3D would also work. The graphics routines serve as an interface to either a fast microprocessor such as an Intel Pentium class processor or a dedicated graphics chip such as are widely available from companies such as nVidia or ATI. Very compact computers such as the Sony VAIO U750 used in a prototype device are able to update the graphics display as fast as 20 Hz. There is a clear path to even better performance in the near future using recently announced multicore microprocessors and graphics chipsets.

[0081] If the user has decided to end the program, it quits in Step 550. Otherwise, user and sensor inputs are gathered in Step 515 and the loop begins again.

[0082] FIG. 6 shows a view frustum used in rendering computer graphics. The frustum is a mathematical construct that is used in deciding which objects from a graphics database should be drawn on a display. Briefly, a database is culled for objects that lie within or partly within a frustum. Objects that lie at least partly within the frustum are rendered on the display in proper perspective according to the direction from which they are viewed. The database need only store the location, shape and orientation of each object once since it is drawn in proper perspective according to graphics routines using the current view frustum.

[0083] In FIG. 6, point "V" 605 is the viewpoint or origin of the view frustum. Vector 610 is the boresight or direction that the frustum is pointing as referenced to the x, y, z coordinate frame. The angular extent of the frustum is bounded by lines 615, 620, 625 and 630. The extent of the frustum is bounded by distances away from the origin " d_{near} " 635 and " d_{far} " 640. The volume that lies within these bounds is the frustum. The graphics routine or scene graph builds a draw list by culling objects from the database that lie in or near the frustum. The tremendous advances in computer graphics made in response to the demand for video games have included wide ranging use of graphics techniques that were unheard of or impossible to realistically implement just a few years ago.

[0084] The "registration problem" mentioned above is common to all synthetic vision systems that simultaneously display actual real-time images and digitally created graphics superimposed upon one another. Registration is the task of getting the two image sources to line up properly with each other. Most registration problems can be traced to errors in the handheld synthetic vision device's estimate of its position or attitude. Position errors become most important when displayed objects are close to the user or to one another. Attitude errors are most important for distant objects. Increasing distance reduces the effect of position error. As distance increases, attitude error comprises a greater and greater fraction of the total error while total error decreases to the point where attitude error is the only contributor to it.

[0085] Luckily, according to an aspect of the invention, while registration errors themselves are fundamentally limited by the accuracy of position and attitude sensing hardware, there are display techniques that reduce a user's perception of registration errors. Further, there are some cases in which users are naturally comfortable accepting registration errors even when they are plainly apparent. FIG. 7 illustrates (in a top down view) a user holding a handheld synthetic

vision device and the lateral extent of two different fields of view that might be displayed on it.

[0086] In the figure a user 705 is holding and looking at the display of a handheld synthetic vision device 710. If synthetic vision device 710 were replaced by a transparent piece of glass the user's angular field of view through the glass would be bounded by lines 730 which form an angle "a" with boresight 720 or equivalently with line 715 which is parallel to boresight 720. On the other hand it is advantageous in many situations to display a scene with a wider field of view such as that bounded by lines 725 which form an angle "b" with boresight 720 and line 715. This expanded field of view, while not literally reproducing what one would see through a glass window, seems natural to most users. According to an aspect of the invention the expanded field of view has several advantages in a handheld synthetic vision device. First of all, more information is displayed. Second, each pixel in the display corresponds to a greater distance in the scene being viewed. The problem of registration is easier with an expanded field of view. The requirements for position and attitude accuracy are not as stringent as they are for a narrower view.

[0087] FIG. 8 shows a person using a synthetic vision device to look at an object behind an opaque wall. A close up view of the display of the device is also shown. In the figure, person 805 is holding a synthetic vision device 810. An enlarged view 812 of the device as seen by the user is also illustrated. The person is using his synthetic vision device to see a tank 850 located behind wall 845. The tank 850 is depicted on the display 815 of the synthetic vision device 810, 812 as an outline shape filled in with a diamond pattern 830. A video image 820 of wall 845 also appears on the display.

[0088] Synthetic vision device 810, 812 is equipped with a range finder. The range finder measures the distance 860 to the first optically or acoustically opaque object along the boresight, in this case wall 845. The location of tank 850 is known to device 810, 812 because the tank has sent its position information to the synthetic vision device via a wireless data link. Therefore the device can calculate the distance 855 between itself and the tank by comparing its position and the tank's position. According to an aspect of the invention the style in which tank 850 is rendered on display 815 indicates whether or not it is the closest object to device 810, 812. In the figure, the tank is not the closest object; it is farther away than wall 845. Therefore the tank is shown with a distinctive fill pattern 830. Other styles could also be used to distinguish near and far objects; for example color or shading. However, it is the combination of the range finder, position information for a database object (e.g. the tank), and the ability of the synthetic vision device to calculate and compare distances that lets the synthetic vision device deduce which objects are closer to it than others. The near-to-far ordering is indicated on the display by displaying objects in different styles or even shapes.

[0089] An arrow 835 also appears on display 815. According to an aspect of the invention arrows on the display are useful to point to off-screen objects. For example, a user of a handheld synthetic vision device might decide to mark a spot in a view displayed on his display for future reference. If the synthetic vision device were an advanced cell phone, a user could point the device toward his car in a large parking lot and push a button or other user input device to tell the synthetic vision device to remember where his car is parked. Later, upon returning to the parking lot, the user would look at the display of the synthetic vision device to find out which way to